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Evaluation of Treatment Performance in TPH Removal from Soil: A Comparative Study of Baobab and Neem Treatments

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Abstract

This study evaluates the effectiveness of Baobab (Adansonia) and Neem (Azadirachta indica) in powdered form, combined with yeast and NPK fertilizer, for the bioremediation of Total Petroleum Hydrocarbons (TPH) in polluted swampy and clay soils. Over an 84-day period, both treatments significantly enhanced TPH degradation, with Neem showing slightly better performance overall. In swampy soil, TPH removal ranged from 97.78% (Baobab) to 98.50% (Neem), while in clay soil, it ranged from 97.38% (Baobab) to 97.69% (Neem). The degradation rates varied depending on treatment weight, with higher treatment weights resulting in more effective TPH removal. In swampy soil, Baobab's TPH degradation increased from 60.79% at 20g to 97.78% at 100g, while Neem's degradation rose from 64.95% to 98.50%. In clay soil, Baobab's degradation increased from 66.89% to 97.38%, and Neem's degradation increased from 69.74% to 97.69%. The results also showed that Baobab was more effective during the first 42 days in clay soil, but after 42 days, Neem slightly outperformed Baobab, likely due to its higher nutrient content promoting microbial degradation. The findings suggest that both Baobab and Neem, when combined with yeast and NPK, are effective and sustainable bioremediation agents for TPH removal, with Neem showing a slight edge, particularly in swampy soils. This highlights the potential of using plant-based treatments for soil decontamination, offering an eco-friendly and cost-effective alternative to conventional methods.

Keywords: Baobab, neem, total petroleum hydrocarbons (TPH), bioremediation, swampy soil, clay soil, powdered form, yeast, NPK, degradation, nutrient content, microbial activity

INTRODUCTION

Soil contamination by petroleum hydrocarbons (TPH) is a significant environmental issue that poses a threat to soil health, groundwater quality, and ecosystems. Petroleum products, including crude oil and refined products, often contaminate soil through spills, leaks, and improper disposal. These hydrocarbons, being toxic and persistent, can hinder soil fertility and microbial activity, leading to long-term environmental degradation. Conventional methods of petroleum hydrocarbon remediation, such as chemical treatments, thermal desorption, and excavation, are often costly, disruptive, and environmentally hazardous. As a result, the search for more sustainable, cost-effective, and environmentally friendly alternatives has led to the exploration of bioremediation techniques using natural amendments like plants, organic matter, and microorganisms [1].

Bioremediation, specifically the use of plants and organic amendments to degrade contaminants in soil, offers a promising solution to TPH pollution. Plants can contribute to soil

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decontamination by promoting microbial degradation through the release of root exudates that enhance microbial activity and by providing organic matter that acts as a nutrient source for hydrocarbon-degrading bacteria. Among the various plant species considered for bioremediation, Baobab (*Adansonia*) and Neem (*Azadirachta indica*) have gained attention due to their rich nutrient profiles and potential to support the biodegradation process [2].

Baobab, commonly known for its fruit, is native to Africa and is recognized for its high vitamin content and nutritional value. The leaves of the Baobab tree are also rich in nitrogen, phosphorus, and other essential nutrients, which are known to stimulate the growth of microorganisms that play a crucial role in the degradation of hydrocarbons. Neem, on the other hand, is a widely used medicinal plant with proven antimicrobial properties. It contains compounds, such as azadirachtin, which have been found to promote microbial degradation of contaminants in the soil. Additionally, Neem's high nutrient content, particularly nitrogen and phosphorus, makes it a suitable candidate for bioremediation [3].

The addition of NPK (Nitrogen, Phosphorus, and Potassium) fertilizer and yeast as part of the bioremediation process further enhances the degradation of petroleum hydrocarbons. NPK fertilizers supply essential nutrients that foster the growth of hydrocarbon-degrading bacteria, which are crucial for breaking down TPH compounds. Yeast, a type of microorganism, can also contribute to the biodegradation process by producing enzymes that aid the breakdown of hydrocarbons into simpler, less toxic compounds [4].

The effectiveness of bioremediation treatments can vary significantly based on several factors, including the type of soil, the nature of the contaminant, and the environmental conditions. Swampy soils, which are often rich in organic matter and moisture, can support higher microbial activity compared to drier clay soils, which are more compact and have lower nutrient availability. Therefore, understanding the performance of different bioremediation agents in different soil types is essential for optimizing the use of plant-based treatments in TPH-contaminated environments [5].

This study aims to evaluate the performance of Baobab and Neem, both in powdered form and combined with yeast and NPK fertilizer, for the removal of TPH from polluted swampy and clay soils. By assessing TPH degradation over time and comparing the effects of varying treatment weights, the study seeks to determine the most effective bioremediation strategy. The findings of this research will contribute to the growing body of knowledge on the use of plant-based amendments for soil decontamination and provide valuable insights into the potential of Baobab and Neem as sustainable bioremediation agents for TPH removal from contaminated soils [6–8].

METHODOLOGY

Materials and Methods

This study was conducted to evaluate the performance of two plant-based treatments**,** Baobab (*Adansonia*) and Neem (*Azadirachta indica*)**,** in powdered form combined with yeast and NPK fertilizer, for the bioremediation of Total Petroleum Hydrocarbons (TPH**)** in polluted swampy and clay soils. The experiment focused on assessing the degradation efficiency of TPH under different treatment weights and over varying time periods. Detailed descriptions of the materials, treatment preparations, and experimental setup are provided below.

Soil Preparation

- *Two distinct soil types were selected for the study:* swampy soil and clay soil. These soils were chosen due to their differing physical properties and their potential influence on bioremediation performance.
- *Swampy soil:* This soil type was sourced from a local wetland area characterized by high moisture content and organic matter. It is typically rich in nutrients and supports a high microbial

population. The soil was sieved through a 2mm mesh to remove any large debris and homogenized to ensure consistency in the experiment.
- *Clay soil:* Clay soil was collected from a nearby agricultural site, known for its low permeability and compact structure. Like swampy soil, it was sieved to remove large particles and homogenized.

Both soils were subjected to initial analysis for key properties, including pH, moisture content, organic matter content, and texture, to determine the baseline conditions before treatment application. The moisture content of swampy soil was naturally higher than that of clay soil, and this factor was accounted for when determining the irrigation needs of each soil type during the study.

Bioremediation Treatments

The bioremediation treatments included Baobab and Neem**,** both in powdered form, along with yeast and NPK fertilizer as additional amendments to enhance the microbial degradation of TPH. The following outlines the preparation and application of each treatment:

- *Baobab (Adansonia):* Baobab leaves were dried, ground into a fine powder, and stored in airtight containers to preserve their nutrient content. The powdered Baobab was used as an organic amendment in both swampy and clay soils. Its rich nitrogen and phosphorus content were expected to support microbial growth and facilitate TPH degradation.
- *Neem (Azadirachta indica):* Like Baobab, Neem leaves were harvested, dried, ground into powder, and stored. Neem is known for its antimicrobial properties and its ability to stimulate the growth of hydrocarbon-degrading bacteria in the soil. Its use in this study was to determine its effectiveness in promoting TPH removal from contaminated soils.
- *Yeast:* Yeast, specifically *Saccharomyces cerevisiae*, was selected for its ability to produce enzymes that aid in the breakdown of organic compounds, including hydrocarbons. A pre-cultured yeast solution was prepared by dissolving 10 g of yeast in 1 liter of sterile water and allowed to incubate for 24 hours at room temperature before adding to the soil.
- *NPK Fertilizer:* The NPK fertilizer used in this study had a balanced ratio of nitrogen (15%), phosphorus (15%), and potassium (15%), which were essential nutrients to stimulate the growth of microorganisms capable of hydrocarbon degradation. The fertilizer was applied at a concentration of 100 g per kg of soil in each treatment plot.
- *Contaminant Addition:* TPH contamination was introduced to the soil by adding a standard mixture of crude oil (50 ml of crude oil per kg of soil). The crude oil was thoroughly mixed into the soil to achieve uniform distribution. The initial TPH concentration in each soil type was measured using standard methods for petroleum hydrocarbon analysis.
- *Moisture and Irrigation Management:* Throughout the experiment, the moisture content of the soil was monitored and maintained at approximately 60% of the soil's field capacity. This was achieved by regular irrigation with distilled water, ensuring that the swampy soil remained consistently moist, while the clay soil was irrigated as needed to maintain its moisture levels.
- *Incubation Period:* The pots were incubated in the greenhouse under controlled temperature (25°C ± 2°C) and light conditions (12-hour photoperiod) to simulate optimal growth conditions for microbial activity. The treatment samples were monitored for TPH degradation at regular intervals of 14, 28, 42, 56, 70, and 84 days.

Data Collection and Analysis

At each sample time, the following data were collected:

- *TPH Concentration:* The remaining TPH concentration in each soil sample was measured by extracting hydrocarbons from the soil using a solvent extraction method (e.g., Soxhlet extraction with hexane) followed by gas chromatography (GC) for quantification. The degradation efficiency was expressed as the percentage of TPH removed from the soil.
- *Microbial Activity:* Soil samples were also analyzed for microbial activity by measuring the soil respiration rate using a respirometer. This allowed for the assessment of microbial growth in

response to the treatments, particularly in terms of the number of hydrocarbon-degrading bacteria present in each soil sample.

- *Statistical Analysis:* The data were statistically analyzed using Analysis of Variance (ANOVA) to determine the significance of differences in TPH degradation between treatments and soil types. A significant level of $p < 0.05$ was considered for all statistical tests. Tukey's HSD test was used to identify significant differences in TPH degradation among treatments at different time intervals.

RESULTS AND DISCUSSION

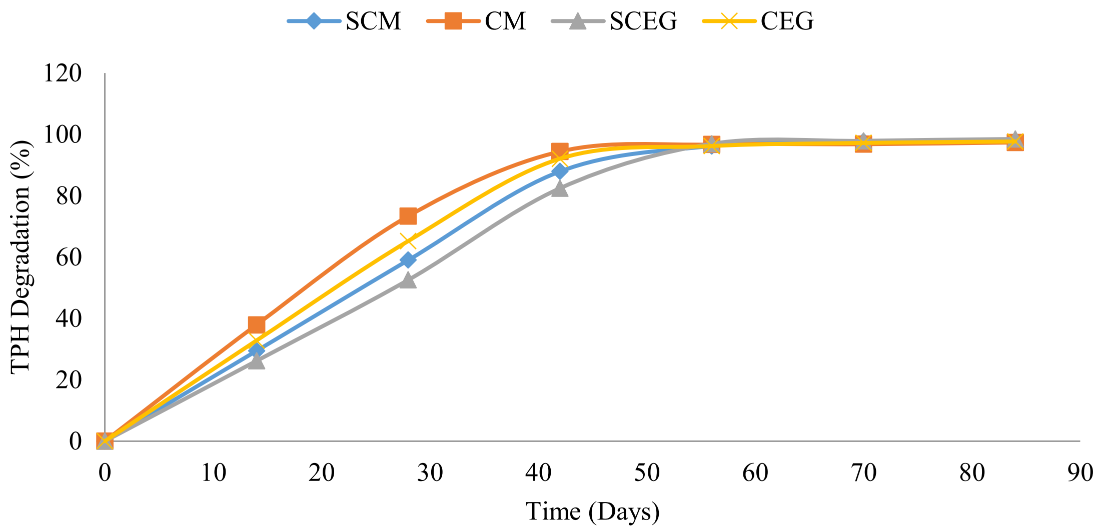

Figure 1. Performance of treatments in swampy soil and clay soils after 84 days.

As shown in Figure 1, the TPH degradation performance of Baobab and Neem treatments in swampy and clay soils over 84 days. The results revealed that the percentage of TPH removed from the soil increased with time, but the degradation rate varied depending on the treatment. On day 84, TPH removal in swampy soil ranged from 97.78% (Baobab in swampy soil) to 98.50% (Neem in swampy soil), while in clay soil, the TPH degradation was between 97.38% (Baobab in clay soil) and 97.69% (Neem in clay soil). Initially, Baobab treatments in clay soil exhibited the highest degradation rates for the first 42 days. However, after this period, the performance of Neem in swampy soil slightly outperformed other treatments.

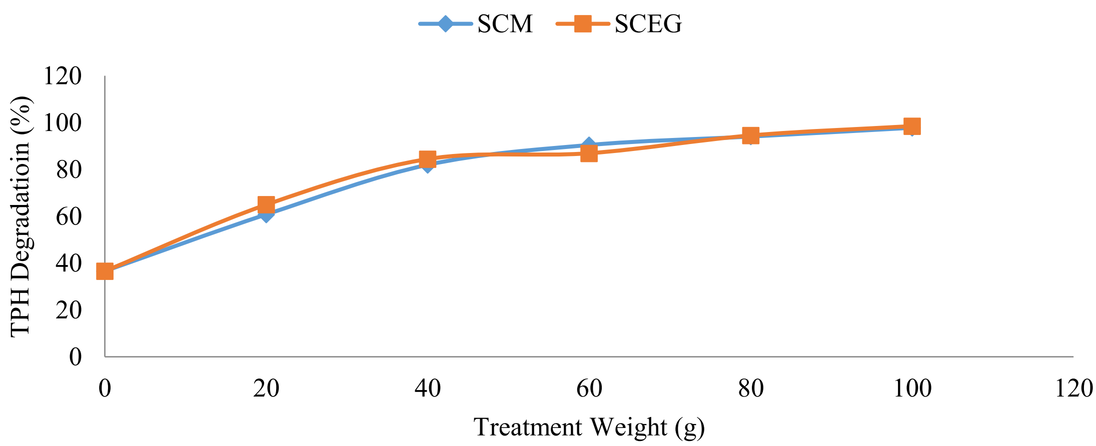

Figure 2. Comparison of TPH degradation.

In Figure 2, the TPH degradation percentage at varying treatment weights in swampy soil is illustrated. It was observed that the degradation percentage increased with the treatment weight. On the 84th day, the performance of Neem in swampy soil, although not significantly higher, edged out Baobab in the same soil type. TPH degradation with Baobab increased from 60.79% at 20 g treatment weight to 97.78% at 100 g, while Neem degradation increased from 64.95% to 98.50%. These findings suggest that increasing treatment weight improves the overall efficacy of TPH removal.

Figure 3 shows a similar trend, with TPH degradation percentage increasing as treatment weight increased. Neem treatment in clay soil slightly outperformed Baobab treatment at various weights, with degradation percentages ranging from 66.89% to 97.38% for Baobab and from 69.74% to 97.69% for Neem at the 100g treatment weight. Although the difference was marginal, Neem treatment demonstrated a consistent edge in both soil types.

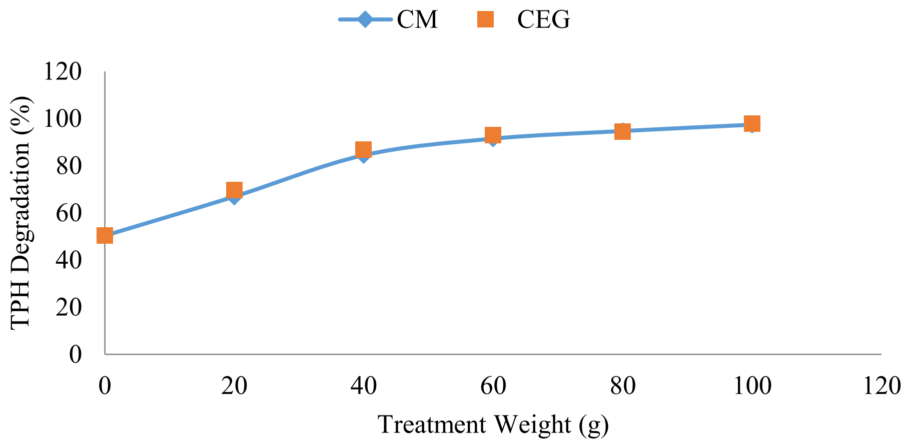

Figure 3. Comparison of TPH degradation**.**

DISCUSSION

The results from this study highlight the potential of both Baobab and Neem as effective bioremediating agents for TPH removal. While both treatments showed significant degradation of hydrocarbons, Neem treatment in swampy soil generally yielded superior performance. The increase in TPH removal is likely due to the higher nitrogen and phosphorus content in soils amended with Neem, which promotes the growth of hydrocarbon-degrading bacteria. This finding aligns with previous studies by [9, 10], and others, which reported a correlation between nutrient-rich amendments and improved biodegradation rates.

In the early stages of treatment (first 42 days), Baobab treatments in clay soil were more efficient, possibly due to the different microbial dynamics in the two soil types. However, beyond this period, Neem treatments in swampy soils gradually outperformed Baobab, suggesting that the swampy soil environment may be more conducive to the sustained microbial activity promoted by Neem's nutrient profile.

CONCLUSIONS

This study demonstrates that both Baobab and Neem are effective in removing TPH from polluted soils, with Neem in swampy soil showing a slight edge over Baobab in overall performance. The higher nutrient content in Neem-amended soils likely contributed to the superior hydrocarbon degradation rates observed, particularly in the later stages of the study. These findings suggest that plant-based treatments, such as Neem and Baobab, could serve as viable, environmentally friendly alternatives for the bioremediation of TPH-contaminated soils. Future studies should explore the interaction between soil type, microbial communities, and the specific plant treatments used to optimize bioremediation strategies for TPH-contaminated sites.

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